IB

10 Gases

Visualizing Concepts

10.2 At constant temperature and volume, pressure depends on total number of particles (Charles' Law). In order to reduce the pressure by a factor of 2, the number of particles must be reduced by a factor of 2. At the lower pressure, the container would have half as many particles as at the higher pressure.

10.3. (a) At constant pressure and temperature, the container volume is directly proportional to the number of particles present (Avogadro's Law). As the reaction proceeds, 3 gas molecules are converted to 2 gas molecules, so the container volume decreases. If the reaction goes to completion, the final volume would be 2/3 of the initial volume.

(b) At constant volume, pressure is directly proportional to the number of particles (Charles' Law). Since the number of molecules decreases as the reaction proceeds, the pressure also decreases. At completion, the final pressure would be 2/3 the initial pressure.

10.5 (a) Partial pressure depends on the number of particles of each gas present. Red has the fewest particles, then yellow, then blue. $P_{red} < P_{yellow} < P_{blue}$

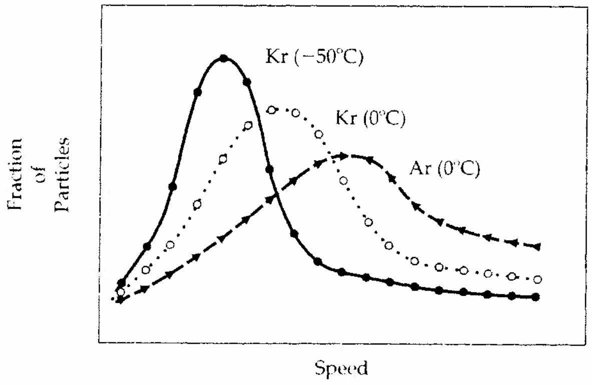
(b) $P_{gas} = \chi_{gas} P_t$. Calculate the mole fraction, χ_{gas} = [mol gas / total moles] or [particles gas / total particles]. This is true because Avogadro's number is a counting number, and mole ratios are also particle ratios.

χ_{red} = 2 red atoms / 10 total atoms = 0.2; P_{red} = 0.2(0.90 atm) = 0.18 atm

χ_{yellow} = 3 yellow atoms / 10 total atoms = 0.3; P_{yellow} = 0.3(0.90 atm) = 0.27 atm

χ_{blue} = 5 blue atoms / 10 total atoms = 0.5; P_{blue} = 0.5(0.90 atm) = 0.45 atm

10.6



10.8 (a) Total pressure is directly related to total number of particles (or total mol particles). P(ii) < P(i) = P(iii)

(b) Partial pressure of He is directly related to number of He atoms (yellow) or mol He atoms. P_{He}(iii) < P_{He}(ii) < P_{He}(i)

(c) Density is total mass of gas per unit volume. We can use the atomic or molar masses of He (4) and N_2(28), as relative masses of the particles.

$$\text{mass(i)} = 5(4) + 2(28) = 76$$

$$\text{mass(ii)} = 3(4) + 1(28) = 40$$

$$\text{mass(iii)} = 2(4) + 5(28) = 148$$

Since the container volumes are equal, d(ii) < d(i) < d(iii).

(d) At the same temperature, all gases have the same "avg" kinetic energy. The average kinetic energies of the particles in the three containers are equal.

Gas Characteristics; Pressure

10.10 (a) Because gas molecules are far apart and in constant motion, the gas expands to fill the container. Attractive forces hold liquid molecules together and the volume of the liquid does not change.

(b) H_2O and CCl_4 molecules are too dissimilar to displace each other and mix in the liquid state. All mixtures of gases are homogeneous. (See Solution 10.9 (c)).

(c) Because gas molecules are far apart, the mass present in 1 mL of a gas is very small. The mass of a gas present in 1 L is on the same order of magnitude as the mass of a liquid present in 1 mL.

10.12 $P = m \times a/A$; $1\ \text{Pa} = 1\ \text{kg/m} \bullet \text{s}^2$; $A = 3.0\ \text{cm} \times 4.1\ \text{cm} \times 4 = 49.2 = 49\ \text{cm}^2$

$$\frac{262\ \text{kg}}{49.2\ \text{cm}^2} \times \frac{9.81\ \text{m}}{\text{s}^2} \times \frac{(100)^2\text{cm}^2}{1\ \text{m}^2} = 5.224 \times 10^5 \frac{\text{kg}}{\text{m} \bullet \text{s}^2} = 5.2 \times 10^5\ \text{Pa}$$

$$P_{\text{total}} = P_{\text{atm}} + P_{H_2O} = 0.95\ \text{atm} + 1.061\ \text{atm} = 2.011 = 2.0\ \text{atm}$$

10.14 Using the relationship derived in Solution 10.13 for two liquids under the influence of gravity, $(d \times h)_{lid} = (d \times h)_{Hg}$. At 752 torr, the height of an Hg barometer is 752 mm.

$$\frac{1.20\ \text{g}}{1\ \text{mL}} \times h_{lid} = \frac{13.6\ \text{g}}{1\ \text{mL}} \times 760\ \text{mm};\ h_{lid} = \frac{13.6\ \text{g/mL} \times 752\ \text{mm}}{1.20\ \text{g/mL}} = 8.52 \times 10^3\ \text{mm} = 8.52\ \text{m}$$

10.16 The mercury would fill the tube completely; there would be no vacuum at the closed end. This is because atmospheric pressure will support a mercury column higher than 70 cm, while our tube is only 50 cm. No mercury flows from the tube into the dish and no vacuum forms at the top of the tube.

10.18 (a) $0.850\ \text{atm} \times \dfrac{760\ \text{torr}}{1\ \text{atm}} = 646\ \text{torr}$

(b) $785\ \text{torr} \times \dfrac{101.325\ \text{kPa}}{760\ \text{torr}} = 105\ \text{kPa}$

10.34 Find the volume of the tube in cm^3; $1\ \text{cm}^3 = 1$ mL.

$r = d/2 = 2.5\ \text{cm}/2 = 1.25 = 1.3\ \text{cm};\ h = 5.5\ \text{m} = 5.5 \times 10^2\ \text{cm}$

$V = \pi r^2 h = 3.14159 \times (1.25\ \text{cm})^2 \times (5.5 \times 10^2\ \text{cm}) = 2.700 \times 10^3\ \text{cm}^3 = 2.7\ \text{L}$

$$PV = \frac{g}{MM}RT;\ g = \frac{MM \times PV}{RT};\ P = 1.78\ \text{torr} \times \frac{1\ \text{atm}}{760\ \text{torr}} = 2.342 \times 10^{-3} = 2.34 \times 10^{-3}\ \text{atm}$$

$$g = \frac{20.18\ \text{g Ne}}{1\ \text{mol Ne}} \times \frac{\text{K} \bullet \text{mol}}{0.08206\ \text{L} \bullet \text{atm}} \times \frac{2.342 \times 10^{-3}\ \text{atm} \times 2.700\ \text{L}}{308\ \text{K}} = 5.049 \times 10^{-3} = 5.0 \times 10^{-3}\ \text{g Ne}$$

10.36 $P_{O_3} = 3.0 \times 10^{-3}$ atm; $T = 250$ K; $V = 1$ L (exact)

$$\#\ \text{of}\ O_3\ \text{molecules} = \frac{PV}{RT} \times 6.022 \times 10^{23}$$

$$\# = \frac{3.0 \times 10^{-3}\ \text{atm} \times 1\ \text{L}}{250\ \text{K}} \times \frac{\text{K} \bullet \text{mol}}{0.08206\ \text{L} \bullet \text{atm}} \times \frac{6.022 \times 10^{23}\ \text{molecules}}{\text{mol}}$$

$$= 8.8 \times 10^{19}\ O_3\ \text{molecules}$$

10.38 (a) $V = 0.250\ \text{L},\ T = 23°\text{C} = 296\ \text{K},\ n = 2.30\ \text{g}\ C_3H_8 \times \dfrac{1\ \text{mol}\ C_3H_8}{44.1\ \text{g}\ C_3H_8} = 0.052154$

$= 0.0522$ mol

$$P = \frac{nRT}{V} = 0.052154\ \text{mol} \times \frac{0.08206\ \text{L} \bullet \text{atm}}{\text{K} \bullet \text{mol}} \times \frac{296\ \text{K}}{0.250\ \text{L}} = 5.07\ \text{atm}$$

(b) STP = 1.00 atm, 273 K

$$V = \frac{nRT}{P} = 0.052154\ \text{mol} \times \frac{0.08206\ \text{L} \bullet \text{atm}}{\text{K} \bullet \text{mol}} \times \frac{273\ \text{K}}{1.00\ \text{atm}} = 1.1684 = 1.17\ \text{L}$$

(c) $°\text{C} = 5/9\ (°\text{F} - 32°);\ \text{K} = °\text{C} + 273.15 = 5/9\ (130°\text{F} - 32°) + 273.15 = 327.59 = 328\ \text{K}$

$$P = \frac{nRT}{V} = 0.052154\ \text{mol} \times \frac{0.08206\ \text{L} \bullet \text{atm}}{\text{K} \bullet \text{mol}} \times \frac{327.59\ \text{K}}{0.250\ \text{L}} = 5.608 = 5.61\ \text{atm}$$

10.40 $V = 65.0\ \text{L},\ T = 23°\text{C} = 296\ \text{K},\ P = 16{,}500\ \text{kPa} \times \dfrac{1\ \text{atm}}{101.325} = 162.84 = 163\ \text{atm}$

(a) $$g = \frac{MM \times PV}{RT};\ g = \frac{32.0\ \text{g}\ O_2}{1\ \text{mol}\ O_2} \times \frac{\text{K} \bullet \text{mol}}{0.08206\ \text{L} \bullet \text{atm}} \times \frac{162.84\ \text{atm}}{296\ \text{K}} \times 65.0\ \text{L}$$

$$= 1.39446 \times 10^4\ \text{g}\ O_2 = 13.9\ \text{kg}\ O_2$$

(b) $$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{16{,}500\ \text{kPa} \times 65.0\ \text{L} \times 273\ \text{K}}{296\ \text{K} \times 101.325\ \text{kPa}} = 9.76 \times 10^3\ \text{L}$$

(c) $$T_2 = \frac{P_2T_1}{P_1} = \frac{150.0\ \text{atm} \times 296\ \text{K}}{16{,}500\ \text{kPa}} \times \frac{101.325\ \text{kPa}}{1\ \text{atm}} = 272.7 = 2.73\ \text{K}$$

(d) $$P_2 = \frac{P_1V_1T_2}{V_2T_1} = \frac{16{,}500\ \text{kPa} \times 65.0\ \text{L} \times 297\ \text{K}}{55.0\ \text{L} \times 296\ \text{K}} = 19{,}566 = 1.96 \times 10^4\ \text{kPa}$$

10.42 mass $= 1800 \times 10^{-9}\ \text{g} = 1.8 \times 10^{-6}\ \text{g};\ V = 1\ \text{m}^3 = 1 \times 10^3\ \text{L};\ T = 273 + 10°\ \text{C} = 283\ \text{K}$

(a) $$P = \frac{g\,RT}{MM \times V};\ P = \frac{1.8 \times 10^{-6}\ \text{g Hg} \times 1\ \text{mol Hg}}{200.6\ \text{g Hg}} \times \frac{0.08206\ \text{L} \bullet \text{atm}}{\text{K} \bullet \text{mol}} \times \frac{283\ \text{K}}{1 \times 10^3\ \text{L}}$$

$$= 2.1 \times 10^{-10}\ \text{atm}$$

(b) $$\frac{1.8\times10^{-6}\text{ g Hg}}{1\text{ m}^3}\times\frac{1\text{ mol Hg}}{200.6\text{ g Hg}}\times\frac{6.022\times10^{23}\text{ Hg atoms}}{1\text{ mol Hg}}=5.4\times10^{15}\text{ Hg atoms/m}^3$$

(c) $$1600\text{ km}^3\times\frac{1000^3\text{ m}^3}{1\text{ km}^3}\times\frac{1.8\times10^{-6}\text{ g Hg}}{1\text{ m}^3}=2.9\times10^{6}\text{ g Hg/day}$$

Further Applications of the Ideal-Gas Equation

10.44 (c) $CO_2(g)$ is least dense. For gases at the same conditions, density is directly proportional to molar mass, and CO_2 has the smallest molar mass.

10.46 (b) Xe atoms have a higher mass than N_2 molecules. Because both gases at STP have the same number of molecules per unit volume, the Xe gas must be denser.

10.48 (a) $d=\frac{\text{MM}\times P}{RT}$; MM = 146.1 g/mol, T = 28°C = 301 K, P = 678 torr

$$d=\frac{146.1\text{ g}}{1\text{ mol}}\times\frac{\text{K}\bullet\text{mol}}{0.08206\text{ L}\bullet\text{atm}}\times\frac{678\text{ torr}}{301\text{ K}}\times\frac{1\text{ atm}}{760\text{ torr}}=5.28\text{ g/L}$$

(b) $$\text{MM}=\frac{dRT}{P}=\frac{7.135\text{ g}}{1\text{ L}}\times\frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{mol}}\times\frac{285\text{ K}}{743\text{ torr}}\times\frac{760\text{ torr}}{1\text{ atm}}=171\text{ g/mol}$$

10.50 $$\text{MM}=\frac{gRT}{PV}=\frac{0.846\text{ g}}{0.354\text{ L}}\times\frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{atm}}\times\frac{373\text{ K}}{752\text{ torr}}\times\frac{760\text{ torr}}{1\text{ atm}}=73.9\text{ g/mol}$$

10.52 $$n_{H_2}=\frac{P_{H_2}V}{RT};\ P=814\text{ torr}\times\frac{1\text{ atm}}{760\text{ torr}}=1.071=1.07\text{ atm};\ T=273+21°\text{C}=294\text{ K}$$

$$n_{H_2}=1.071\text{ atm}\times\frac{\text{K}\bullet\text{mol}}{0.08206\ \text{L}\bullet\text{atm}}\times\frac{53.5\text{ L}}{294\text{ K}}=2.3751=2.38\text{ mol }H_2$$

$$2.3751\text{ mol }H_2\times\frac{1\text{ mol }CaH_2}{2\text{ mol }H_2}\times\frac{42.10\text{ g }CaH_2}{1\text{ mol }CaH_2}=50.0\text{ g }CaH_2$$

10.54 Balance the chemical equation.

Then, g $C_5H_{12}\rightarrow$ mol $C_5H_{12}\rightarrow$ mol $O_2\rightarrow$ V O_2 at given P, T.

$$C_5H_{12}(l)+8O_2(g)\rightarrow 5CO_2(g)+6H_2O(g)$$

$$2.50\text{ g }C_5H_{12}\times\frac{1\text{ mol }C_5H_{12}}{72.15\text{ g }C_5H_{12}}\times\frac{8\text{ mol }O_2}{1\text{ mol }C_5H_{12}}=0.2772=0.277\text{ mol }O_2$$

$$V=\frac{nRT}{P}=0.2772\text{ mol }O_2\times\frac{296\text{ K}}{0.980\text{ atm}}\times\frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{mol}}=6.87054=6.87\text{ L }O_2$$

According to Avogadro's law, mole ratios are volume ratios for gases at the same pressure and temperature. Use mole ratios from the chemical equation to calculate volumes of $CO_2(g)$ and $H_2O(g)$.

$$6.87054\text{ L }O_2\times\frac{5\,CO_2}{8\,O_2}=4.29\text{ L }CO_2;\ 6.87054\text{ L }O_2\times\frac{6\,H_2O}{8\,O_2}=5.15\text{ L }H_2O$$

10.56 The gas sample is a mixture of $C_2H_2(g)$ and $H_2O(g)$. Find the partial pressure of C_2H_2, then moles CaC_2 and C_2H_2.

$$P_t = 726\text{ torr} = P_{C_2H_2} + P_{H_2O}.\ P_{H_2O}\text{ at }26°\text{C} = 25.21\text{ torr}$$

$$P_{C_2H_2} = (726\text{ torr} - 25.21\text{ torr}) \times \frac{1\text{ atm}}{760\text{ torr}} = 0.9221 = 0.922\text{ atm}$$

$$0.887\text{ g CaC}_2 \times \frac{1\text{ mol CaC}_2}{64.10\text{ g}} \times \frac{1\text{ mol C}_2\text{H}_2}{1\text{ mol CaC}_2} = 0.013838 = 0.0138\text{ mol C}_2\text{H}_2$$

$$V = 0.013838\text{ mol} \times \frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{mol}} \times \frac{299\text{ K}}{0.9221\text{ atm}} = 0.368\text{ L C}_2\text{H}_2$$

Partial Pressures

10.58 (a) The partial pressure of gas A is **not affected** by the addition of gas C. The partial pressure of A depends only on moles of A, volume of container, and conditions; none of these factors changes when gas C is added.

(b) The total pressure in the vessel **increases** when gas C is added, because the total number of moles of gas increases.

(c) The mole fraction of gas B **decreases** when gas C is added. The moles of gas B stay the same, but the total moles increase, so the mole fraction of B (n_B/n_t) decreases.

10.60 (a) $$2.50\text{ g CH}_4 \times \frac{1\text{ mol CH}_4}{16.04\text{ g CH}_4} = 0.15586 = 0.156\text{ mol CH}_4$$

$$P_{CH_4} = \frac{nRT}{V} = 0.15586\text{ mol} \times \frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{mol}} \times \frac{288\text{ K}}{2.00\text{ L}} = 1.842 = 1.84\text{ atm}$$

$$2.50\text{ g C}_2\text{H}_4 \times \frac{1\text{ mol C}_2\text{H}_4}{28.05\text{ g C}_2\text{H}_4} = 0.08913 = 0.0891\text{ mol C}_2\text{H}_4$$

$$P_{C_2H_4} = \frac{nRT}{V} = 0.08913\text{ mol C}_2\text{H}_4 \times \frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{mol}} \times \frac{288\text{ K}}{2.00\text{ L}} = 1.053 = 1.05\text{ atm}$$

$$2.50\text{ g C}_4\text{H}_{10} \times \frac{1\text{ mol C}_4\text{H}_{10}}{58.12\text{ g C}_4\text{H}_{10}} = 0.04301 = 0.0430\text{ mol C}_4\text{H}_{10}$$

$$P_{C_4H_{10}} = \frac{nRT}{V} = 0.04301\text{ mol} \times \frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{mol}} \times \frac{288\text{ K}}{2.00\text{ L}} = 0.5083 = 0.508\text{ atm}$$

(b) $P_t = 1.842\text{ atm} + 1.053\text{ atm} + 0.508\text{ atm} = 3.403 = 3.40\text{ atm}$

10.62 $$V\ C_4H_{10}O(l) \xrightarrow{\text{density}} \text{mass } C_4H_{10}O \rightarrow \text{mol } C_4H_{10}O \rightarrow P_{C_4H_{10}O}\text{ at given V, T.}$$

$$P_t = P_{N_2} + P_{O_2} + P_{C_4H_{10}O};\ T = 273.15 + 35.0°\text{C} = 308.15 = 308.2\text{ K}$$

(a) $$4.00\text{ mL C}_4\text{H}_{10}\text{O} \times \frac{0.7134\text{ g C}_4\text{H}_{10}\text{O}}{\text{mL}} \times \frac{1\text{ mol C}_4\text{H}_{10}\text{O}}{74.12\text{ g C}_4\text{H}_{10}\text{O}} = 0.0385\text{ mol C}_4\text{H}_{10}\text{O}$$

$$P = \frac{nRT}{V} = 0.03850\text{ mol} \times \frac{308.15}{5.00\text{ L}} \times \frac{0.08206\text{ L}\bullet\text{atm}}{\text{K}\bullet\text{mol}} = 0.1947 = 0.195\text{ atm}$$

(b) $P_t = P_{N_2} + P_{O_2} + P_{C_4H_{10}O} = 0.751\text{ atm} + 0.208\text{ atm} + 0.195\text{ atm} = 1.154\text{ atm}$

10.64 $n_{N_2} = 10.25\,g\ N_2 \times \frac{1\,mol}{28.02\,g} = 0.3658\,mol$; $n_{H_2} = 2.05\,g\ H_2 \times \frac{1\,mol}{2.016\,g} = 1.0169 = 1.02\,mol$

$n_{NH_3} = 7.63\,g\ NH_3 \times \frac{1\,mol}{17.03\,g} = 0.448\,mol$; $n_t = 0.3658 + 1.0169 + 0.4480 = 1.8307$

$= 1.83\,mol$

$$P_{N_2} = \frac{n_{N_2}}{n_t} \times P_t = \frac{0.3658}{1.8307} \times 2.35\,atm = 0.470\,atm$$

$$P_{H_2} = \frac{1.0169}{1.8307} \times 2.35\,atm = 1.31\,atm;\ P_{NH_3} = \frac{0.4480}{1.8307} \times 2.35\,atm = 0.575\,atm$$

10.66 (a) $n_{O_2} = 5.08\ g\ O_2 \times \frac{1\,mol}{32.00\,g} = 0.159\,mol$; $n_{N_2} = 7.17\,g\ N_2 \times \frac{1\,mol}{28.02\,g} = 0.256\,mol$

$n_{H_2} = 1.32\ g\ H_2 \times \frac{1\,mol}{2.016\,g} = 0.655\,mol$; $n_t = 0.159 + 0.256 + 0.655 = 1.070\,mol$

$$\chi_{O_2} = \frac{n_{O_2}}{n_t} = \frac{0.159}{1.07} = 0.149;\ \chi_{N_2} = \frac{n_{N_2}}{n_t} = \frac{0.256}{1.07} = 0.239$$

$$\chi_{H_2} = \frac{0.655}{1.07} = 0.612$$

(b) $P_{O_2} = n \times \frac{RT}{V}$; $P_{O_2} = 0.159\,mol \times \frac{0.08206\,L\bullet atm}{K\bullet mol} \times \frac{288\,K}{12.40\,L} = 0.303\,atm$

$$P_{N_2} = 0.256\,mol \times \frac{0.08206\,L\bullet atm}{K\bullet mol} \times \frac{288\,K}{12.40\,L} = 0.488\,atm$$

$$P_{H_2} = 0.655\,mol \times \frac{0.08206\,L\bullet atm}{K\bullet mol} \times \frac{288\,K}{12.40\,L} = 1.25\,atm$$

10.68 Calculate the pressure of the gas in the second vessel directly from mass and conditions using the ideal-gas equation.

(a) $P_{SO_2} = \frac{gRT}{M\,V} = \frac{4.00\,g\ SO_2}{64.07\,g\ SO_2/mol} \times \frac{0.08206\,L\bullet atm}{K\bullet mol} \times \frac{298\,K}{10.0\,L} = 0.15267$

$= 0.153\ atm$

(b) $P_{N_2} = \frac{gRT}{M\,V} = \frac{2.35\,g\ N_2}{28.01\,g\ N_2/mol} \times \frac{0.08206\,L\bullet atm}{K\bullet mol} \times \frac{298\,K}{10.0\,L} = 0.20516$

$= 0.205\ atm$

(c) $P_t = P_{SO_2} + P_{N_2} = 0.15267\,atm + 0.20516\,atm = 0.358\,atm$

Kinetic-Molecular Theory; Graham's Law

10.70 (a) False. The average kinetic energy per molecule in a collection of gas molecules is the same for all gases at the same temperature.

b) True.

(c) False. The molecules in a gas sample at a given temperature exhibit a distribution of kinetic energies.

(d) True.

10.72 Newton's model provides no explanation of the effect of a change in temperature on the pressure of a gas at constant volume or on the volume of a gas at constant pressure. On the other hand, the assumption that the average kinetic energy of gas molecules increases with increasing temperature explains Charles' Law, that an increase in temperature requires an increase in volume to maintain constant pressure.

10.74 (a) They have the same number of molecules (equal volumes of gases at the same temperature and pressure contain equal numbers of molecules).

(b) N_2 is more dense because it has the larger molar mass. Since the volumes of the samples and the number of molecules are equal, the gas with the larger molar mass will have the greater density.

(c) The average kinetic energies are equal (statement 5, section 10.7).

(d) CH_4 will effuse faster. The lighter the gas molecules, the faster they will effuse (Graham's Law).

10.76 (a) *Plan.* The greater the molecular (and molar) mass, the smaller the rms speed of the molecules. Calculate the molar mass of each gas, and place them in decreasing order of mass and increasing order of rms speed. *Solve.*

$CO = 28$ g/mol; $SF_6 = 146$ g/mol; $H_2S = 34$ g/mol; $Cl_2 = 71$ g/mol;
$HBr = 81$ g/mol. In order of increasing speed (and decreasing molar mass):

$SF_6 < HBr < Cl_2 < H_2S < CO$

(b) *Plan.* Follow the logic of Sample Exercise 10.14. *Solve.*

$$u_{CO} = \sqrt{\frac{3RT}{M}} = \left(\frac{3 \times 8.314 \text{ kg} \bullet \text{m}^2/\text{s}^2 \bullet \text{K} \bullet \text{mol} \times 300 \text{ K}}{28.0 \times 10^{-3} \text{ kg/mol}}\right)^{1/2} = 5.17 \times 10^2 \text{ m/s}$$

$$u_{Cl_2} = \left(\frac{3 \times 8.314 \text{ kg} \bullet \text{m}^2/\text{s}^2 \bullet \text{K} \bullet \text{mol} \times 300 \text{ K}}{70.9 \times 10^{-3} \text{ kg/mol}}\right)^{1/2} = 3.25 \times 10^2 \text{ m/s}$$

As expected, the lighter molecule moves at the greater speed.

10.78 $$\frac{\text{rate}\,^{235}\text{U}}{\text{rate}\,^{238}\text{U}} = \sqrt{\frac{238.05}{235.04}} = \sqrt{1.0128} = 1.0064$$

There is a slightly greater rate enhancement for $^{235}U(g)$ atoms than $^{235}UF_6(g)$ molecules (1.0043), because ^{235}U is a greater percentage (100%) of the mass of the diffusing particles than in $^{235}UF_6$ molecules. The masses of the isotopes were taken from *The Handbook of Chemistry and Physics.*

10.80 The time required is proportional to the reciprocal of the effusion rate.

$$\frac{\text{rate (X)}}{\text{rate } (O_2)} = \frac{105 \text{ s}}{31 \text{ s}} = \left[\frac{32 \text{ g } O_2}{MM_x}\right]^{1/2}; \; MM_x = 32 \text{ g } O_2 \times \left[\frac{105}{31}\right]^2 = 370 \text{ g/mol (two sig figs)}$$

Nonideal-Gas Behavior

10.82 Ideal-gas behavior is most likely to occur at high temperature and low pressure, so the atmosphere on Mercury is more likely to obey the ideal-gas law. The higher temperature on Mercury means that the kinetic energies of the molecules will be larger